

INTEGRATING ECOLOGICAL RISK ASSESSMENT AND HAZARDS ANALYSIS

**A Pilot Project for the
Proposed Los Alamos Waste Treatment and Storage Facilities**

Summary and Lessons Learned

Conducted by

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1.0. INTRODUCTION

This report provides a summary of the Ecological Risk Assessment Pilot Project and describes lessons learned from it [see Kelly et al. (1995) for details]. This pilot project was conducted to augment the Preliminary Hazards Analysis (PHA) and the limited Probabilistic Risk Assessment (PRA) conducted by the Los Alamos Probabilistic Risk and Hazard Assessment Group (TSA-11) for the proposed Environmental Systems and Waste Characterization Group's Waste Treatment and Storage Facilities at the TA-63 Site of Los Alamos National Laboratory. This pilot explored the possibility of using an ecological risk assessment approach to explicitly incorporate environmental consequence analysis into the PHA/PRA process for the hazardous waste facilities. This work was funded by Defense Programs (DP) 34, The Office of Environmental Support.

2.0. BACKGROUND

A legitimate criticism of many PHAs and PRAs is that hazards ranking, accident-sequence prioritization, and risk evaluation are based on human health consequences and do not consider ecological impacts. Although a PHA/PRA is supposed to consider impacts to the public, on-site and off-site workers, and the environment, the environment is rarely addressed explicitly. At best, it is included by giving a high ranking to accidents that have the potential for significant off-site releases. However, as shown in the PHA for the Waste Treatment and Storage Facilities, this approach does not guarantee that accidents with the greatest potential for ecological damage are identified.

The PHA for the Waste Treatment and Storage Facility identified the release of toxic gases from compressed cylinders as the most serious risk scenario. This scenario was determined to be the most serious because of the potential extent of the release and because the toxic gases presented the greatest risks to human health. However, this scenario is not the most serious in terms of environmental effects at TA-63 and the surrounding areas. The potential accidents with the most serious environmental effects are those that release long-lasting toxic materials to surface soils and plants. The hazardous waste facilities PHA provides a classic example of what can happen when human health effects and off-site contaminant dispersal levels are used as surrogates for ecological impacts.

The problem of inadequately addressing ecological impacts in the waste facilities PHA, and in PHAs in general, is recognized by TSA-11. The purpose of this pilot project is to explore an approach to remedy this problem. The approach used in the pilot is based on ecological risk assessment methods and is tiered to provide a timely, cost-effective procedure and to be consistent with the techniques traditionally used in PHAs.

The first phase of this tiered approach combines a conservative ecological screening model with the worst-case accident scenario (based on ecological criteria) to determine if ecological impacts can be excluded from further investigation or if they require a more detailed assessment. If a more detailed assessment is required, the screening model is used to narrow this investigation by identifying the sensitive ecological/geographical areas, the major contaminants of concern, and the most sensitive species.

An indication of possible risk, based on the conservative screening model, does not necessarily mean that there is significant risk. In this case, a more detailed analysis is necessary. The detailed analysis, which uses more realistic and less conservative assumptions, may show that there is no significant risk of adverse ecological impacts. Depending on the complexity of the more detailed analysis, it can be part of the PHA or can be included in the PRA. If a significant risk is identified, the more detailed analysis can be used to identify mitigation strategies to reduce or eliminate the risk. The second phase of this tiered approach uses an ecological transport model (ECOTRAN) to evaluate ecological impacts when more detailed assessments are required.

3.0. SCREENING ASSESSMENT

3.1. Conservative Ecotoxicological Screening Levels

A cornerstone of the screening assessment is the development of conservative ecotoxicological screening levels (ESALs). These screening levels are defined as concentrations of potential contaminants in soil, air, and water such that, if a release of contamination based on an accident scenario does not yield contaminant concentrations greater than the ESALs, then the accident does not present an ecological hazard. The ESALs vary depending on the species and are derived from no observed adverse effects levels (NOAELs) as reported in the Environmental Protection Agency's (EPA's) primary toxicological databases, the Integrated Risk Information System (IRIS) and the Health Effects Summary Tables (HEAST). Basing the ESALs on these EPA toxicological and health effects databases is important for establishing their credibility and defensibility.

The NOAELs are estimated doses to animals based on laboratory tests, and uncertainties in these estimates are included in the ESAL calculations by dividing the NOAELs by a factor of 10. This method for addressing uncertainty is consistent with what is done for human health risk assessments. The adverse impacts reported in the EPA databases encompass a variety of effects, including tissue damage, decreased reproduction, and increased tumor incidence. This approach for determining ecotoxicological screening levels also is being used by the environmental restoration programs at Oak Ridge National Laboratory and at Rocky Flats Environmental Technology Site.

3.2. Ecological Endpoints for the Screening Assessment

Three key, or indicator, species were used in the screening assessment in this pilot: deer mice, coyotes, and mule deer. These three animal species are considered to be good indicator species for the mammals in the Los Alamos environment because they represent populations that have small, medium, and large home ranges and body sizes; represent several different types of feeding habits; span three consumer levels in the food web; and have very different metabolic and reproductive rates. Animal species were chosen because of the availability of ecotoxicological data and because there is evidence that protecting animals tends to protect plants and microbes and perhaps reptiles.

In the screening assessment, the ESALs for these animals were compared with the contaminant levels resulting from the worst-case accident scenario. If the contaminant levels are below the ESALs for all contaminants, then ecological risks are determined not to be an issue in terms of potential accident scenarios for this facility. Contaminant levels above the conservative ESALs do not indicate that there is a significant risk of adverse ecological impacts, only that the possibility cannot be ruled out with this simple screening approach and a more detailed analysis is required.

3.3. Worst-Case Accident Scenario

Ecotoxicology and waste management experts were consulted to determine the appropriate worst-case accident scenario based on ecological effects. The experts considered the following factors to establish the worst-case scenario.

- The composition and dynamics of the surrounding ecosystems
- The possible inventory of contaminants at the Waste Treatment and Storage Facilities
- The ecotoxicity of the possible contaminants
- The fate and transport of contaminants in the environment
- The mode of storage
- The plausibility of off-site release

Based on these factors, the worst-case scenario was determined to be the release to the environment of the total inventories of lead, mercury, polychlorinated biphenyls (PCBs), tetrachloroethylene (TCE), and uranium.

The initiating events for the worst-case release were identified as a seismic event, an internal fire, or an external fire that would lead to collapse or partial collapse of the storage building. The worst-case scenario assumed that the contaminants escaped the containment building, flowed through the storm sump, and finally were released to the environment through the detention pond. The frequency of this worst-case scenario (based on the results of the PHA) proved to be less than 10^{-6} , which is below a frequency of concern. Despite its low frequency, this scenario was evaluated in the screening process because if no adverse ecological impacts were identified under this scenario, there would be no need for further ecological impact assessment.

3.4. Results from the Screening Assessment

Table 1 lists the results of the conservative screening assessment for three of the contaminants—uranium, mercury, and TCE. In this table, the first column (Areas) represents seven areas surrounding the site that could be affected by the accident release. These areas are on the mesa top, canyon sides, and canyon bottom, and they have different plant and animal compositions and distributions. Test Study Area (TS) 1 is the area that encompasses the site of the proposed facility.

Table 1 shows the usefulness of this screening approach to focus a more detailed investigation. The screening assessment eliminates TCE as a contaminant of concern, identifies uranium as the major contaminant of concern, points to areas TS 1 and TS 2 as the most susceptible to adverse ecological impacts and establishes the deer mouse as the most sensitive species.

TABLE 1
CONSERVATIVE SCREENING ASSESSMENT RESULTS

AREAS (PRIORITIZED)	CONTAMINANT		
	Uranium	Mercury	TCE
TS 1	XXX	X	W
TS 2	XXX	X	W
TS 7	XX	W/O	W
TS 3	X	W/O	W
TS 6	X	W/O	W
TS 4	W/O	W/O	W
TS 5	W/O	W/O	W

- XXX** Concentrations from accident above the ESALs for all species
- XX** Concentrations above ESALs for deer mice and coyotes
- X** Concentrations above ESALs for deer mice only
- W/O** Concentrations below the ESALs * 10 for all species (no correction for uncertainties in estimates)
- W** Concentrations below the ESALs (corrected for uncertainties) for all species

A slightly more detailed screening analysis includes animal home range information. In this case, the ESAL is adjusted by the area of the animal's home range divided by the area of contamination to reflect the reality that the deer mule and coyote do not get all of their food from the contaminated area. Because all areas are much smaller than either the home range of the deer mule or coyote, the adjusted ESAL in all cases is larger than the unadjusted ESAL. Using this screening approach for these three contaminants, only the deer mouse, with a home range smaller than all seven areas, shows the potential for an adverse ecological effect from the worst-case accident scenario.

4.0. ECOTRAN APPLICATION

The ESAL estimates are based on constant ingestion and inhalation rates, as well as a constant fraction of soil consumption. To test the appropriateness of these simplifying assumptions and examine the validity of the ESAL calculations, a dynamic ecological transport and uptake model, ECOTRAN, is used. ECOTRAN more realistically describes the animal's uptake of contaminants based on complex modeling of the flow of organic and inorganic contaminants, including radionuclides, through the specified plant and animal environments. ECOTRAN models climate effects, soil types, food web relationships, predation, starvation, transport of contaminants within animals including fetal transport, and gestation. This model has been used extensively at Los Alamos and field data have been consistent with model predictions. The model was also used in the Pantex environmental impact statement (EIS).

The ECOTRAN model provides a useful tool for studying in more detail those cases that the screening model identifies as presenting a potential ecological hazard. For example, home range effects can be modeled realistically rather than using simplifying assumptions of homogeneous distributions of food over the range of the animal. In the same vein, the effects of heterogeneity in the contaminant distributions and seasonal variation of contaminant uptake can be evaluated.

In this pilot, the ECOTRAN model was used to evaluate the conservative assumptions of the screening model, and to explore in detail the ecological effects in TS 1. TS 1 is the area that the screening assessment pointed to as most susceptible to adverse ecological impacts from the worst-case accident scenario.

The results of the complex ECOTRAN simulation were consistent with the results of the simplified, conservative screening model in terms of risk-based prioritization decisions. For example ECOTRAN was used to predict a set of limiting body, organ, and tissue concentrations that are protective of populations and/or individuals of a given animal type. These limiting concentrations were based on the assumption that soil concentrations of the contaminants of concern were at ESAL levels. ECOTRAN also was used to predict limiting body, organ, and tissue levels based on soil concentrations at accidental release levels. The limiting ESAL levels were compared with the accidental release levels to determine if the worst-case accident presented a potential ecological hazard. Table 2 displays the ECOTRAN comparison results and the screening assessment comparison results for uranium, mercury, and TCE at TS 1. This table shows that the detailed ECOTRAN simulation supports the findings of the simplified screening assessment for TS 1; TCE is eliminated as a contaminant of concern and uranium is identified as the major contaminant of concern.

5.0. LESSONS LEARNED FROM THE PILOT PROJECT

The pilot project demonstrates that the conservative screening approach based on ecological risk assessment techniques can be an effective tool for specifically addressing environmental consequences in the PHA. However, issues remain before a final approach can be recommended. These issues are described below.

TABLE 2
ECOTRAN RESULTS COMPARED WITH
CONSERVATIVE SCREENING ASSESSMENT RESULTS FOR TS 1

	CONTAMINANT		
	Uranium	Mercury	TCE
Screening Comparison	XXX	X	W
ECOTRAN -Body	XXX	W/O	W
ECOTRAN - Muscle	XXX	W/O	W
ECOTRAN - Liver	XXX	W/O	W
ECOTRAN-Kidney	XXX	W/O	W
ECOTRAN-Bone	XXX	W/O	W
ECOTRAN-FAT	XXX	W/O	W

XXX Limiting concentrations from accident above the limiting ESAL concentrations for all species
X Limiting concentrations above limiting ESAL concentrations for deer mice only
W/O Limiting concentrations below the limiting ESAL concentrations * 10 for all species (no correction for uncertainties in estimates)
W Limiting concentrations below the limiting ESALs (corrected for uncertainties) for all species

- In this pilot, three indicator species were selected for the ecological endpoints: deer mice, mule deer, and coyotes. Ultimately, consensus must be reached on the appropriate species or criteria for selecting species to be used as endpoints in a conservative screening model. Consensus on these criteria must be reached through discussions with decision-makers, experts, and key stakeholders.
- In the screening model approach used in this pilot, conservative ESALs were developed for individual contaminants. The potential combined effects of multiple contaminants were ignored. In the final approach, combined effects from multiple contaminants must be addressed.
- The ESALs are based on sublethal impacts to individuals. These sublethal individual effects may not cause an ecologically significant impact on the population. Unless the accident release affects threatened or endangered species, the concern is for population effects, not individual effects. Therefore, the ESALs may be overly conservative. On the other hand, ESALs are derived from NOAELs that are generally determined from laboratory experiments on small numbers of animals. Therefore, there is uncertainty in the estimate of the NOAEL. This uncertainty is accounted for by dividing the NOAEL by a factor of 10. It is possible that this uncertainty factor is not adequate and the ESALs are not conservative enough for large population effects. Although our experience indicates that ESALs based on the methods used in this pilot tend to be overly conservative (often below

levels found in background concentrations for naturally occurring constituents), to resolve this apparent dichotomy a population effects model is needed.

The pilot screening approach used the worst-case accident scenario to determine if ecological impacts were of concern or could be excluded from further analyses. Given that ecological impacts need to be considered in further analyses, the screening model also provides a defensible method for including ecological risk in the PHA risk ranking of potential accident scenarios. For example, the risk ranking for ecological impacts could be based on the number of areas affected, the number of contaminants of concern, and the number of species at risk. Future work should explore the utility of using this approach in conjunction with traditional PHA risk ranking methods to prioritize potential accident scenarios.

A final lesson learned is one that is not specifically related to the ecological risk assessment model but to the process of including ecological risk assessment in the PHA. The PHA for the proposed waste disposal facilities was performed by a multidisciplinary team consisting of experts in the areas of engineering, risk analysis, process chemistry, and waste management. The ecological expert was invited into the process after the PHA was completed. Experience shows that the ecologist should be included at the beginning of the PHA, have training in PHA methods, be at least a part-time member of the PHA team, and participate in the formal PHA review process. Including the ecologist in the entire PHA process enhances communication between the ecologist and other experts, who are likely to have very different orientations, and ensures that these diverse experts are focused on common goals.

REFERENCE

Kelly, E., M. Kramer, C. McDaniel, M. K. Sasser, D. Stack, and T. Gallegos, "Integrating Ecological Risk Assessment and Hazards Analysis: A Pilot Project for the Proposed Los Alamos Waste Treatment and Storage Facilities," Los Alamos National Laboratory document LA-UR-95-2555 (1995).